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Quarterly Technical Report - Report No. 1
December 19, 1991 - March 31, 1992
DARPA DICE Manufacturing Optimization

Robert V.E. Bryant
Linda J. Lapointe

Raytheon Company

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Defense Advanced Research
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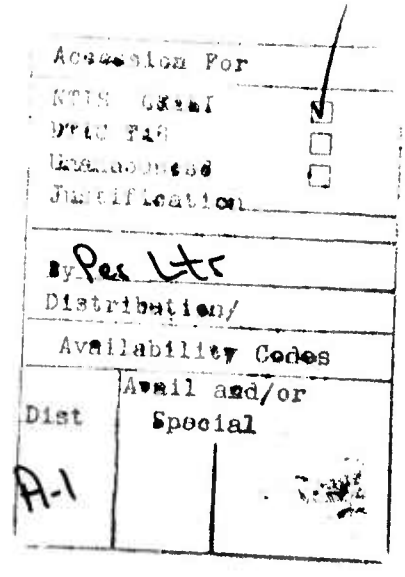

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1. Summary

This is the Quarterly Technical Report for the DARPA DICE Manufacturing Optimization. The purpose of the Manufacturing Optimization (MO) system is to enable each manufacturing specialist to participate in the product/process development activity concurrently. The system will consist of a set of tools to model the manufacturing processes and centralize the various process tradeoffs. The subject of this report is the technical work accomplished during the first quarter of the contract. This report describes the evaluation of the DICE tools (ROSE, CMS, PCB, CM, and RM) being considered for incorporation into the MO system and the MO Operational Concept.

Raytheon proposed to use ROSE to store and manage the process models and analysis data for the MO system. As part of the evaluation process of ROSE, we developed a set of test cases to demonstrate the applicability of the ROSE DBMS to adequately model the manufacturing process models and analysis data. Based on the results of our sample test case, we believe that the ROSE DBMS is able to handle the various types of manufacturing process model and analysis data required in the MO environment. We recommended the continued use of the ROSE DBMS as the repository for all the process data files for the manufacturing processes and operations, as well as, the various analysis results for the MO system.

Raytheon proposed to use the CMS to provide a mechanism for constraining the product design to process capabilities. Since the pilot site version of the CMS software was unavailable for testing, Raytheon planned a trip to CERC for a demonstration of the CMS and a meeting with the developers. Based on the CERC visit, it was determined that the future versions of CMS will support the product/process constraint mechanism proposed in MO. Raytheon plans on installing the June release of the CMS. Raytheon will continue to develop the process selection functionality and will evaluate the CMS when it is available. If the CMS is not used, the implemented MO process selection functionality will include mechanisms such that it can be integrated into the product team environment as a module.

The Requirements Manager (RM) is a system designed to manage product requirements, specifications and corporate policies to support concurrent engineering. Within the MO program, Raytheon planned to use the RM for manufacturability/producibility guidelines. Raytheon attended a demonstration of the RM V3.0 at the DICE Phase IV Kick-off meeting. According to announced plans, the RM V3.0 will be available for beta test at the end of March and released for production use at the end of June. Raytheon has maintained a dialogue with CIMFLEX and has expressed its interest in being a beta test site.

Raytheon will continue development of MO during the next quarter based on the "Operational Concept Document For the Manufacturing Optimization (MO) System" and the "Description of CE Technology For the Manufacturing Optimization (MO) System" documents developed during the reporting period. Raytheon is in the process of developing the Functional Requirements and Measures of Performance Specification which will be delivered during the next quarter.

2. Introduction

This is the Quarterly Technical Report for the DARPA DICE Manufacturing Optimization. The purpose of the Manufacturing Optimization (MO) system is to enable each manufacturing specialist to participate in the product/process development activity concurrently. The system will consist of a set of tools to model the manufacturing processes and centralize the various process tradeoffs. The subject of this report is the technical work accomplished during the first quarter of the contract. This report describes the evaluation of the DICE tools (ROSE, CMS, PCB, CM, and RM) being considered for incorporation into the MO system and the MO Operational Concept.

The Manufacturing Optimization (MO) system is a conceptual refinement to the original DICE virtual tiger team concept. This refinement is to have a two level approach with a product virtual team having a global view supported by information supplied by lower level "specialized" process virtual teams. The purpose of the Manufacturing Optimization (MO) system is to enable each manufacturing specialist to participate in the product/process development activity concurrently. The system will consist of a set of tools to model the manufacturing processes and centralize the various process tradeoffs. The primary mission of the MO system is in researching and developing a "generalized" design for manufacturing and assembly (DFMA) environment capable of modelling diverse manufacturing processes. The secondary mission is the "user hardening" of existing concurrent engineering technology by applying existing DICE Tools to DFMA. The MO architecture is shown in Figure 2-1.

At the time MO was proposed, Raytheon did a preliminary evaluation of the concurrent engineering tools previously developed under the DICE program. The evaluation consisted of visits to both CERC and Rensselaer Polytechnic Institute (RPI) to attend demonstrations and presentations of DICE tools. Available technical papers for each of the DICE tools were studied by the proposal team. Based on this preliminary evaluation, the ROSE Database Management System (DBMS), Constraint Management System (CMS), and Requirements Manager (RM) were identified as candidates for incorporation into the MO system. An evaluation of those tools, as well as the Project Coordination Board (PCB) and Communications Manager (CM), was conducted during the reporting period. The results of that evaluation are summarized here. Refer to reference 3 for evaluation details.

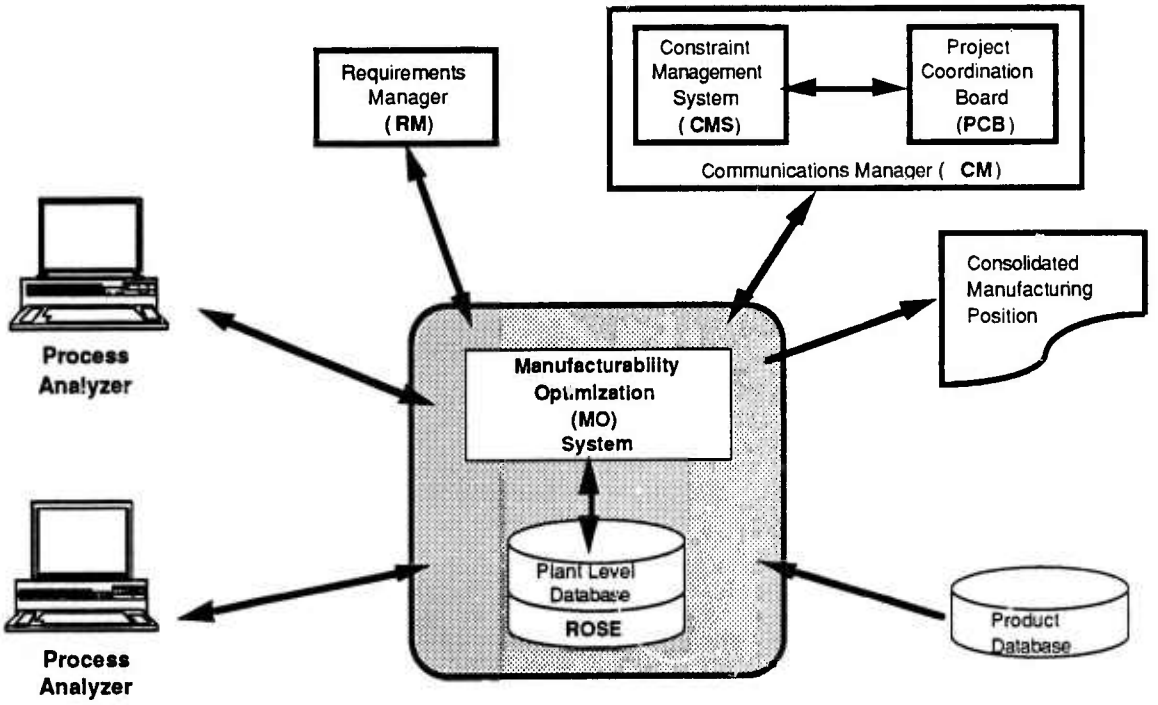


Figure 2-1. Proposed DICE MO Architecture

3. Methods, Assumptions, and Procedures

This section describes the evaluation of the DICE tools that was conducted during the reporting period. These tools include the Rensselaer Object System For Engineering (ROSE), the Constraint Management System (CMS), The Requirement Manager (RM), the Project Coordination Board (PCB), and the Communications Manager (CM).

3.1 DICE Tool Evaluation

3.1.2 ROSE - Rensselaer Object System For Engineering

ROSE is an object-oriented database management system that has been developed for engineering applications and enhanced to support the DICE program. The ROSE Database Management System is a database that supports concurrency using a data model that allows the differences between two design versions to be computed as a delta file. ROSE will be used to store and manage the data files for the manufacturing processes and operations, as well as, the various analysis results. Its proposed use in the MO system is to store the process routing sequence which will enable us to do comparisons of process trade-offs via the delta files. The process database consists of the process selection knowledge base, process/operation data, yield/rework data, guidelines, and recommendations.

The MO process analysis module performs the initial analysis on the design to determine the manufacturing process required to produce the part. This module will take a knowledge based approach that will compare design features and attributes against process capabilities to determine a part's process sequence. There are three levels to the process knowledge: the process, operation, and operational step. The process is an organized group of manufacturing operations sharing characteristics, the operation is a common unit of work that is performed on the part, and the operational step is an elemental unit of work within an operation. Once the process database is populated, evaluation of the design is possible. We plan to store the analysis results in the ROSE DBMS.

Raytheon developed a set of test cases to demonstrate the applicability of the ROSE DBMS to adequately model the manufacturing process models and analysis data. We modelled three levels of the process knowledge in the EXPRESS information modelling language so that we could create (populate) a sample manufacturing process model database. We used the actual process model we stored in ROSE to select two different process plan sequences and store those results in another ROSE database. Finally, we read in the list of process plan results so that we could evaluate the process of capturing results from a ROSE database for the manufacturing advisor module to perform comparisons and summations.

3.1.2 CMS - Constraint Management System

The Constraint Management System allows the user to build constraints into the concurrent engineering process. The system tracks constraints and can notify, or launch an evaluation when constraints are not satisfied. The CMS will be used to manage the constraint placed on the design by the capabilities of the process required by the MO system. The rules that determine the selection (or evaluation) of operations within the MO system can be modelled as a set of constraints. If the constraints are satisfied then the operation can produce the part or feature (based on scope of rule set). If the rules or constraints of the operation are not satisfied then the operation is not valid for use. By interfacing with the constraint manager, these process/operation rules can monitor the design and be informed when the design has exceeded process capabilities.

The CMS will be integrated with the Project Coordination Board and the Communications Manager in a planned September, 1992 release. The Project Coordination Board (PCB) is a system being developed to provide support for the coordination of the product development activities in a cooperative environment. The Communications Manager (CM) is a collection of modules that facilitates distributed computing in a heterogeneous network. It promotes the notion of a virtual network of resources which the project team members can exploit without any prior knowledge of the underlying physical network.

The Constraint Management System is scheduled for a release to DICE pilot sites during the upcoming quarter. The system was not available for on site evaluation at Raytheon at the time of this report. To conduct the evaluation of the CMS without benefit of site installed software, Raytheon planned a visit to CERC to attend a demonstration of the CMS and meet with the developers. The trip coincided with the CERC PCB/CM training session so Raytheon also attended the two day class to gain insight into the functionality of the PCB and CM

3.1.3 RM - Requirements Manager

The Requirements Manager is a system designed to manage product requirements, specifications and corporate policies to support concurrent engineering. The system allows the users to define requirements for a project or incorporate standard requirements through pointers (file name). The system also tracks parties interested in specific requirements and provides notification capabilities based on the status of a requirement. Status updates could include modifications of a requirement, product design driven violations of a requirement, or satisfaction of a requirement.

The purpose of integrating MO manufacturing guideline functionality into the RM is to give the "top level" product development team insight into manufacturing requirements apart from MO analyses.

The latest version of the RM is Version 2.0. Although this version was installed at CERC, it is not supported. While at the DICE Phase IV Kick-off meeting, we attended a demonstration of the RM V3.0. Raytheon has maintained a dialogue with CIMFLEX Teknowledge and has expressed its interest in being a beta test site.

3.2 MO Operational Concept Development

The DICE program has been chartered with developing technology that enables concurrent engineering. Part of the DICE concurrent engineering model is a replication of the human tiger team concept that has been successfully used on small scale projects to bring high quality products to market quickly. The basic tenet of the human tiger team is to have the various specialists contributing to the project co-located.

The MO system will provide a conceptual refinement to the DICE virtual tiger team concept. In the present DICE virtual tiger team model, all functions are represented and linked concurrently to the product design at a single level. MO will provide a two level approach with a virtual product team having a global view supported by information supplied by the virtual process teams. The rationale for this refinement is based on the growing complexity of both the products and supporting development processes. It is increasingly difficult to have one representative adequately support a manufacturing (or logistics) position that involves numerous specialized process areas. In practice, the assigned representative is usually a specialist in one of the process areas and has only generalized knowledge about the other processes. The "virtual process team" would enable representation from all the process areas. The product team would concentrate on using the cost/yield information supplied by the process teams, and determine the best plan by taking into account the existence or implementation of manufacturing, logistics, or test plans. The product team would be responsible for decisions that span cross-functional expertise.

Ideally, the virtual process team is an extension of the product team. It will consist of specialists representing all the various processes. For instance, a process team for a complex electro-mechanical assembly might consist of a PWB Fabrication, Circuit Card Assembly, Cable/Wire Harness, and Sheet Metal representatives. They will have access to the unified product database and will be responsible for the manufacturing inputs to the product team. Each member of the process team will review the design, perform a

DFMA analysis, and make design or process change recommendations. The product team will then negotiate with the process team to arrive at a position (and perhaps alternatives) consistent with the manufacturing plan.

The virtual process team will be supported by a set of tools that implements a concurrent DFMA system. These tools will enable the manufacturing process team to perform individual DFMA analyses, merge and review these analyses, and negotiate trade-offs among the processes. A consolidated report and recommendations is passed back to the product team. The MO system will be composed of five modules: process analysis, yield/rework modeler, cost estimator, guidelines, and manufacturing advisor, as well as, the integration of current DICE tools.

4. Results and Discussion

4.1 DICE Tool Evaluation Results

After installing the Step Tool Kit (ROSE DBMS) and performing the eight tutorial lessons provided in the ROSE Tutorial Manual (reference 6), we felt that we had obtained an understanding of the basic ROSE functionality. We continued by developing a set of test cases to demonstrate the applicability of the ROSE DBMS to adequately model manufacturing process models and analysis data. This involved writing an EXPRESS schema to represent a sample of the process model data, generating the C++ classes with the use of the "express2c++" tool, and writing, compiling and executing various ROSE Applications (C++ programs). The developers learned the basics of the ROSE DBMS with the use of the refcrence and tutorial manuals provided with the software (References 4 and 6). To learn the more advanced features of ROSE, Raytheon plans on attending one of the training sessions conducted by STEP Tools. Raytheon believes that ROSE is quite stable. We encountered no difficulties during the installation or evaluation procedures. Based on the results of our sample test case, we believe that ROSE is able to handle the various types of manufacturing process model and analysis data required in the MO environment so we are planning on continuing the integration efforts with the ROSE System. The EDEX Editor is an editor that has been developed to support EXPRESS schema creation and manipulation for ROSE. EDEX will be used to code and edit the manufacturing process model schema(s).

Since there was no pilot site version of the CMS software available, Raytheon visited CERC to received a demonstration of the current version of the Constraint Management System (CMS). The purpose of the CMS is to provide mechanisms to effectively represent, manage and satisfy the constraints imposed on a product and its development. The possible forms that a Constraints Manager would need include algebraic (*equality/inequality and linear/nonlinear*), numeric (*table look-up*), conditional (*if-then*), logical (*"X and Y"*), bidirectional (i.e. *x^3/(e^2.3) = 3.8y*), and unidirectional (*blackbox*). The types of constraints that the the first pilot site release will be able to handle are the bidirectional constraint represented by algebraic equations (linked to Mathematica™), and the blackbox constraint (unidirectional) which receive input and produce output through the evaluation of an external analysis program. Many of our constraints for the MO system come in the form of conditional and logical constraints. For example, a constraint for the sheet metal pancl/chassis environment could be "IF single_diameter_hole AND material_thickness = 0.125 AND maximum_bend_radius = 0.125 AND minimum_distance_to_edge_of_bend < 0.348 THEN punch ELSE drill_at_assembly". If after the evaluation of the first release of the CMS we continue the integration efforts, we will have to utilize the blackbox constraint

by writing our own external analysis program that would take our constraint format as input and return the result as output.

Since the CMS is scheduled to be integrated with the Project Coordination Board (PCB) and Communications Manager (CM), Raytheon attended a two day training class on the PCB and CM at CERC. The PCB is a system being developed to provide support for the coordination of the product development activities in a cooperative environment, and the CM is a collection of modules that facilitates distributed computing in a heterogeneous network thereby, promoting the notion of a virtual network of resources which the project team members can exploit without any prior knowledge of the underlying physical network. Since the PCB displays the product structure in a hierarchical fashion, Raytheon considered using the PCB as the front-end for the MO data model entry. The limitation of this PCB function is that it can import information into the PCB using the Knowledge Server, but the only output format is its knowledge base (*kb*) file. We were hoping that it would not only be able to import the product structure from the ROSE database, but also to export the product structure to ROSE since our current plan is to store all the MO data in ROSE. The CERC pilot site support leader said that there is plans to provide this type of link because it has been requested by other pilot project sites, but they could not provide us with a delivery date. Since the Knowledge Server is the software that is required to translate data from the ROSE database into the PCB database, we will be requesting a copy of the Knowledge Server from CERC so that we can test the ROSE to PCB link. When Raytheon gets a copy of the pilot site version of the PCB/CM software, we will perform our own internal evaluation which will provide us with a basis for whether or not the systems could be of use in the MO environment. We plan to continue with the developed approach to this constraint manager function, and do not plan to incorporate the CMS, PCB, or CM in the MO design until after careful evaluation of each of the released systems.

The Requirements Manager (RM) is a system designed to manage product requirements, specifications and corporate policies to support concurrent engineering. Within the MO program, Raytheon planned to use the RM for manufacturability/producibility guidelines. Version 2.0 of the RM was installed at CERC, but is not supported. Raytheon decided to wait for the upcoming release, Version 3.0, and not to install V2.0. Raytheon attended a demonstration of the RM V3.0 at the DICE Phase IV Kick-off meeting. According to announced plans, the RM will be available for beta test at the end of March and released for production use at the end of June. Raytheon has maintained a dialogue with CIMFLEX and has expressed its interest in being a beta test site. The purpose of integrating the manufacturing guideline functionality into the RM is to give the "top level" product development team insight into manufacturing requirements apart from MO analyses. Raytheon will continue to develop the MO guideline functionality and will evaluate the RM when it is available. If the RM is

not used, the implemented MO guideline functionality will include mechanisms such that it can be integrated into the product team environment as a module.

4.2 MO System Functions and Characteristics

The MO system will consist of five software modules: process analysis, yield/rework modeler, cost estimator, guidelines, and manufacturing advisor, as well as, the integration of current DICE tools. The process analysis module performs the initial analysis on the design to determine the manufacturing process (a set of operations) required to produce the part. The yield/rework modeler calculates yield and rework values by performing a look up of design features versus an operation. The cost estimator module will calculate cost for each operation used to produce the part. The guidelines module captures design for manufacturing and assembly guidelines and associated recommendations. When guidelines are violated, the violation and the associated recommendation are recorded. The manufacturing advisor analyzes the data generated by the individual analyses and guides the negotiation/trade-off process by identifying major cost drivers and guideline violations. It recommends design alternatives based on the influence of the design parameters on the cost analysis. This module will produce the output of the sub-team that gets passed to the top level team.

The process analysis module performs the initial analysis on the design to determine the manufacturing process (a set of operations) required to produce the part. This module will take a knowledge based approach that will compare design features and attributes against process capabilities to determine a part's process sequence. The actual process will be characterized as a process logic tree representation and selection algorithm where the cost can be based on the process. This representation will provide the ability to focus in on cost drivers. The system will also have the ability to store alternative models of a particular process. This capability will provide the process engineer a means of exploring alternative process approaches and plan process improvements. The ROSE DBMS will be used to store the data associated with the process logic, selection, and analysis results.

One of the major manufacturing cost drivers is production yields. Poor yields increase costs while tying up production capacity and other resources such as engineering support and materials. The yield/rework module will model yields on an operation by operation basis. Design feature values will be assigned contributing yield values. The yield/rework modeler will compute the yield of an operation based on the design features and contributing yields that affect that operation. This module calculates yield and rework values by performing a look up of design features versus an operation. If multiple features affect an operation then a composite value is computed based on defined relationships among the features.

The cost estimator module will calculate cost for each operation used to produce the part. The individual operation cost will be calculated using labor standards, wage rates, and production efficiencies. Each operation cost will then be factored by yield and rework rates to arrive at an estimate.

The guidelines module captures design for manufacturing and assembly guidelines and associated recommendations based on quantitative and qualitative producibility issues. When guidelines are violated, the violation and the associated recommendation are recorded. The guidelines can be evaluated separately, or triggered based on the process analysis. Unlike the process selection constraints, the guideline violations may not cause alternative selection. The result could be an operation cost increase, for instance, the need for non-standard tooling, a yield drop, or a less tangible impact. Each guideline will be accompanied by a recommendation that would be presented through the manufacturing advisor. The manufacturing team will develop guidelines that will give the design team insight into the manufacturing requirements, and can be one source to initiate execution of manufacturability analysis. For example, if heavy ground planes are required, the preferred location is on center layers of multi-layer boards with outer layers symmetrically balanced. The reason for this manufacturing guideline is that non-symmetrical ground planes cause warping of the PWB as a result of temperature cycling. The copper ground plane expands at a rate different than the rest of the PWB and causes deformation.

The manufacturing advisor analyzes the data generated by the individual analyses and guides the negotiation/trade-off process by identifying major cost drivers and guideline violations. It recommends design alternatives based on the influence of the design parameters on the cost analysis. The process routings, guideline violations and recommendations, and cost estimates will be organized such that the effects of each design feature can be reviewed across processes. The advisor organizes the data consolidated within ROSE and summarizes processes, guideline violations, and recommendations. The advisor will facilitate the comparison among the alternatives.

It will provide variance and sensitivity analyses on the cost estimates which will allow the team to look at the total cost variance caused by adopting various design alternatives. As each process runs its analysis on a set of design alternatives the cost estimates can be compared. This will show both the changes in cost of each process and the total change in product cost.

5. Conclusions

The evaluation plan for each of the DICE tools considered for incorporation into the MO system environment, ROSE DBMS, CMS, PCB, CM, and RM, was performed. Table 5-1 contains the summary of the evaluation results.

Based on the results of our sample test case, we believe that ROSE is able to handle the various types of manufacturing process model and analysis data required in the MO environment so we are planning on continuing the integration efforts with the ROSE System.

Since there was no pilot site version of the CMS software available, Raytheon visited CERC to received a demonstration of the current version of the Constraint Management System (CMS). The purpose of the CMS is to provide mechanisms to effectively represent, manage and satisfy the constraints imposed on a product and its development. If after the evaluation of the first release of the CMS we continue the integration efforts, we will have to utilize the blackbox constraint by writing our own external analysis program that would take our constraint format as input and return the result as output.

When Raytheon gets a copy of the pilot site version of the 'CB/CM software, we will perform our own internal evaluation which will provide us with a basis for whether or not the systems could be of use in the MO environment. We plan to continue with the developed approach to this constraint manager function, and do not plan to incorporate the CMS, PCB, or CM in the MO design until after careful evaluation of each of the released systems.

Raytheon will continue to develop the MO guideline functionality and will evaluate the RM when it is available. If the RM is not used, the implemented MO guideline functionality will include mechanisms such that it can be integrated into the product team environment as a module.

Raytheon will continue development of MO during the next quarter based on the "Operational Concept Document For the Manufacturing Optimization (MO) System" and the "Description of CE Technology For the Manufacturing Optimization (MO) System" developed during the reporting period. Raytheon is in the process of developing the Functional Requirements and Measures of Performance Specification which will be delivered during the next quarter.

Table 5-1. Summary of the Evaluation Results

System Under Evaluation	MO Applicability	Maturity/Availability	Conclusion/ Recommendation
ROSE	Model, Store, and Manage Process Model and Analysis Data.	Stable. No difficulty with installation or evaluation procedures.	Plan on continuing integration efforts.
EDEX Editor	Code and edit MO Express Schemas.	No evaluation planned or conducted.	Plan to install.
CMS	Model Process Model Rules as a set of Constraints.	Immature. Not available for pilot site installation until June.	Install and evaluate in June.
PCB	Scheduled for integration with the CMS by the end of September.	Immature. Attended training session, and scheduled for software installation as soon as possible.	Install and evaluate as soon as possible.
CM	Currently integrated with the PCB, and will be required when PCB/CM is integrated with the CMS at the end of September.	Immature. Attended training session, and scheduled for software installation as soon as possible.	Install and evaluate as soon as possible.
RM	Manage manufacturability/ producibility guidelines.	Immature. RM V3.0 not available for pilot installation.	Install and evaluate RM V3.0 when available.

6. Recommendations

Raytheon has evaluated the ROSE system, the Constraint Management System (CMS), and the Requirements Manager, for product maturity and incorporation into the MO program. The evaluation of these tools was expanded to encompass the Project Coordination Board (PCB) and the Communications Manager (CM) because they are closely coupled to the CMS. Raytheon recommends using the ROSE system for MO implementation. At present, the CMS and RM are to immature to commit to for use in MO. The planned release for both the RM and CMS are during the early stage of the MO design cycle. Therefore, Raytheon recommends that both tools are tracked and further evaluation conducted when these tools are released. A final determination will be made at that time.

To better understand the more advanced features of ROSE, attending one of the three day sessions that Step Tools conducts would be of great assistance in our future MO development efforts.

Raytheon will continue to develop the process selection functionality and will evaluate the CMS when it is available. If the CMS is not used, the implemented MO process selection functionality will include mechanisms such that it can be integrated into the product team environment as a module.

Raytheon reviewed the PCB and CM which will be integrated with the September version of the CMS software. The recommended plan is to get the PCB/CM software installed at Raytheon so that we can perform an internal evaluation using sample MO data. During our evaluation, we would be able to determine if the PCB/CM would add any value to the MO environment as an extension to the CMS or as a front-end to the MO process data model entry.

Raytheon will continue to develop the MO guideline functionality and will evaluate the RM when it is available. If the RM is not used, the implemented MO guideline functionality will include mechanisms such that it can be integrated into the product team environment as a module.

Raytheon will continue development of MO during the next quarter. Raytheon is in the process of developing the Functional Requirements and Measures of Performance Specification which will be delivered during the next quarter. A review was held with the DARPA program manager on April 7, 1992. Appendix 1 contains the presentation slides from that review.

7. References

1. BR-20558-1, 14 June 1991, DARPA Initiative In Concurrent Engineering (DICE) Manufacturing Optimization - Volume I - Technical.

2. CDRL No. 0002-AC-1, 19 March 1992, Operational Concept Document For The Manufacturing Optimization (MO) System, Contract No. MDA972-92-C-0020.

3. CDRL No. 0002-AC-2, 19 March 1992, Description of Concurrent Engineering Technology For The Manufacturing Optimization (MO) System, Contract No. MDA972-92-C-0020.

8. Notes

8.1 Acronyms

CAEO	Computer Aided Engineering Operations
CDRL	Contract Data Requirements List
CM	Communications Manager
CMS	Constraint Management System
DARPA	Defense Advanced Research Projects Agency
DBMS	Database Management System
DFMA	Design for Manufacturing and Assembly
DICE	DARPA Initiative In Concurrent Engineering
MO	Manufacturing Optimization
MSD	Missile Systems Division
PCB	Project Coordination Board
OCD	Operational Concept Document
PWB	Printed Wiring Board
RM	Requirements Manager

Appendix I - Quarterly Review Presentation Slides

Raytheon

DARPA DICE MANUFACTURING OPTIMIZATION QUARTERLY REVIEW

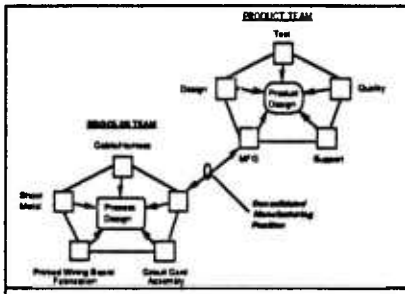
Bob Bryant
Raytheon Company MSD
MSL-CAE Operations
April 7, 1992

Raytheon

Agenda

- MO Overview
- Accomplishments
- Current Activities
- Operational Concept Document Review
- Description of Concurrent Engineering Technology Report Review
- Schedule
- Budget
- Plans
- Closing Remarks/Action Items

Raytheon Manufacturing Optimization (MO) Overview



New Ideas

- Integrate individual process oriented Design for Manufacturing and Assembly (DFMA) analyses into a concurrent engineering environment
- Apply generative process planning techniques to perform DFMA
- Manage manufacturing optimization across functional process areas
- Provide tool for managing/comparing process alternatives

Impact

- Create a virtual team for process engineering
- Multiple manufacturing specialists to participate in product/process design
- Enable design optimization within a manufacturing strategy

Schedule

Year 1 - Develop architecture and design
- Object data structures for manufacturing process
- Process analysis management
- User harden existing DICE tools

Year 2 - Software development and demonstration
- Develop MO software using object oriented programming
- Demonstrate system with advanced packaging PCB module

Raytheon Accomplishments

- CERC and Industry Interaction:

- Attended Package Strategic Research Plan Workshop held at Research Triangle Park in North Carolina to gain a wider perspective on DFMA issues and requirements from a number of industry sources

- Established procedure for Raytheon's interaction with CERC with Dr. Joe Cleetus and Dr. J. Ed Sneckenberger

- MO Architecture Development

- Attended Seminar on the Object Store product from Object Design, Inc. to investigate its applicability to DICE MO program

- Released the MO Operational Concept Document

Raytheon Accomplishments (Cont.)

- Evaluate Suitability of Current DICE Tools:
- Received and installed a copy of the Step Tool Kit Release 1 (ROSE) from Step Tools, Inc.
- Received a copy of the EDEX Editor from Mr. Brion Sarachan of General Electric
- Developed MO test case for ROSE that implemented a subset of functionality required for the MO process analysis module
- Arranged for Raytheon to become a beta test site for Requirements Manager (RM) with Cimflex Teknowledge
- Attended a two day training class at CERC on Project Coordination Board (PCB) and Communications Manager (CM)
- Attended demonstration of Constraint Management System (CMS). Discussed its applicability to MO with CMS developers
- Released the MO Description of CE Technology Report

Raytheon Current Activities

- Performing Object Oriented Analysis of MO System for the Functional Requirements and Measures of Performance Document

Raytheon

DARPA

Operational Concept Document (OCD) Review

Raytheon

DARPA

OCD

- Describes the mission of the MO System, its operational and support environments, the five software modules, and the integration of current DICE tools

MO System Purpose

- Enable each MFG specialist to participate in the product/process development activity concurrently

Mission Needs

- Due to the growing complexity of products and multiplicity of processes, it is difficult for one process engineer to adequately support manufacturability reviews

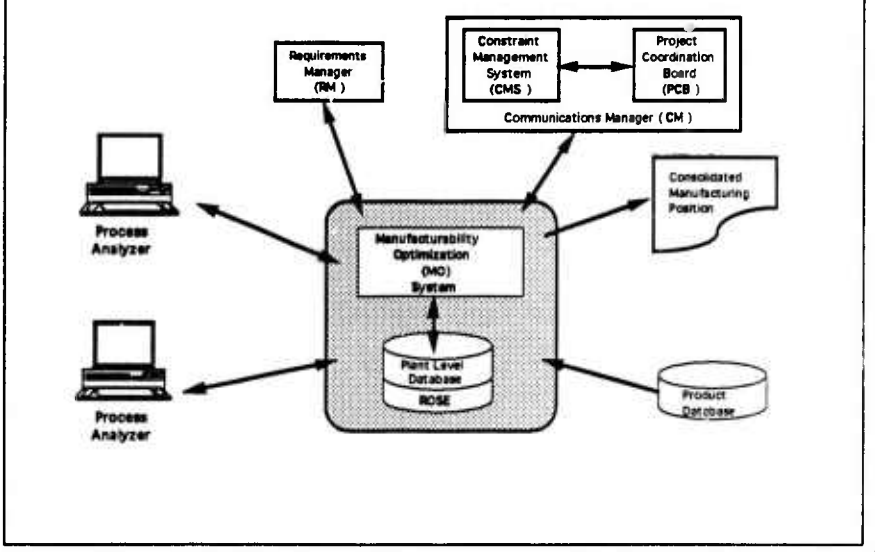
Primary Mission

- Research and develop a "generalized" DFMA environment capable of modelling diverse manufacturing processes

Secondary Mission

- "User Harden" Concurrent Engineering Technology by applying existing DICE tools to DFMA

Raytheon Proposed MO Architecture



Raytheon MO System Modules

Process Analysis

- Performs initial analysis on design to determine the manufacturing process required to produce the part

Yield/Rework Modeler

- Models yield and rework on an operation by operation basis where the design feature values are assigned contributing yield and rework percentages

Cost Estimator

- Calculates cost of each operation used to produce a part by using labor standards, wage rates, and production efficiencies

Guidelines

- Captures DFMA guidelines and associated recommendations based on quantitative and qualitative producibility issues

Manufacturing Advisor

- Analyzes data generated by the individual analyses and guides the negotiation/trade-off process by identifying major cost drivers and guideline violations

Raytheon

Description of
Concurrent Engineering Technology
Review

Raytheon

CE Technology

- Addresses secondary mission of the MO System, "User Hardening" of existing DICE tools
- Outlines Methods, Assumptions, and Procedures used to evaluate ROSE, CMS, and RM
- Identifies Results, Conclusions, and Recommendations of Evaluation

Raytheon ROSE Evaluation

Evaluation Plan:

- Installed Step Tool Kit (ROSE) Release 1
- Performed tutorials to become familiar with functionality
- Modelled a small sample of the process model data in EXPRESS information modelling language
- Developed a series of ROSE Applications (C++ Programs) that created and manipulated ROSE databases

Summary:

System Under Evaluation	MO Applicability	Maturity/Availability	Conclusion/ Recommendation
ROSE	Model, Store, and Manage Process Model and Analysis Data.	Stable. No difficulty with installation or evaluation procedures.	Suitable for MO use. Continue integration efforts.
EDEX Editor	Code and edit MO Express Schemas.	Mature tool. Currently under use at GE & RPI.	Should be used as planned.

Raytheon CMS Evaluation

Evaluation Plan:

- Attend training sessions
- Perform installation and evaluation similar to ROSE evaluation

Summary:

System Under Evaluation	MO Applicability	Maturity/Availability	Conclusion/ Recommendation
CMS	Model Process Model Rules as a set of Constraints.	Immature. Not available for pilot site installation until June.	Install and evaluate in June.
PCB	Support coordination of product/process development activities.	Immature. Not available for pilot site installation.	Install and evaluate as soon as possible.
CM	Support communication among team members. Support distributed computing & database access in a network.	Immature. Not available for pilot site installation.	Install and evaluate as soon as possible.

Raytheon — RM Evaluation

DARPA

Evaluation Plan:

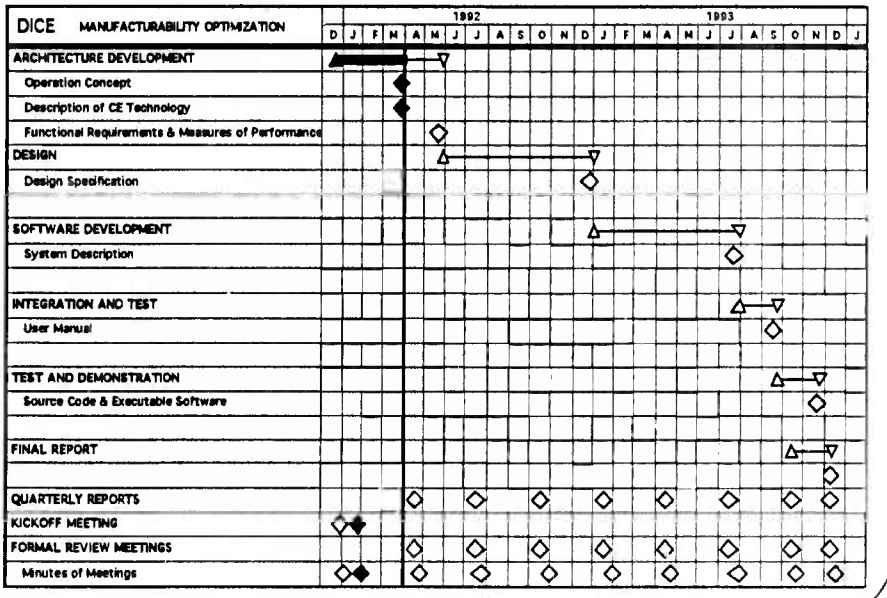
- Obtain RM beta test version (V3.0) from Cimflex
- Attend demonstration and training as needed
- Perform installation and evaluation similar to ROSE evaluation

Summary:

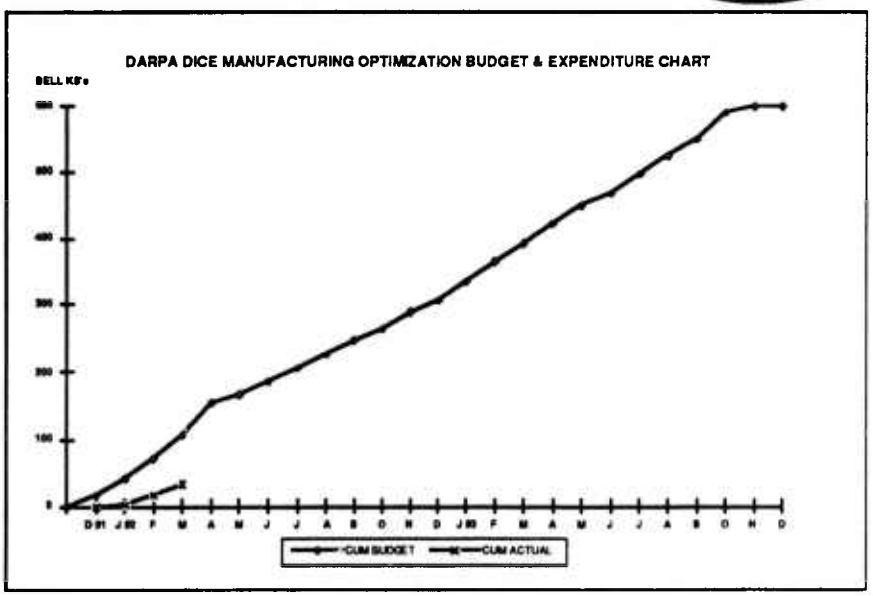
System Under Evaluation	MO Applicability	Maturity/Availability	Conclusion/ Recommendation
RM	Manage manufacturability/ producibility guidelines.	Immature. RM V3.0 not available for pilot site installation.	Install and evaluate RM V3.0 when available.

Raytheon — Schedule

DARPA



Raytheon Budget



Raytheon Plans For Next Quarter

- Publish Meeting Minutes from Review Meeting 4/92
- Host Meeting with Representatives of CERC to Demonstrate Raytheon's Current CE Capabilities and Exchange CE Experience and Guidelines 4/92
- Complete and Release Functional Requirements and Measures of Performance Document 5/92
- Install PCB/CM at Raytheon and Start Evaluation 5/92
- Install RM and Start Evaluation 5/92
- Attend CMS Training,Install and Evaluate at Raytheon 6/92
- Begin Design Specification 6/92

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